
VOLUME 4. AIRCRAFT EQUIPMENT AND OPERATIONAL AUTHORIZATIONS

CHAPTER 1. AIR NAVIGATION, COMMUNICATIONS, AND SURVEILLANCE

SECTION 1. GENERAL NAVIGATION CONCEPTS, POLICIES, AND GUIDANCE

1. GENERAL.

A. This chapter provides an explanation of navigational concepts, direction, and guidance used by FAA inspectors to evaluate requests for authorization to conduct en route operations. It also discusses methods and requirements necessary to approve or deny requests for proposed operations using aircraft and/or navigation systems new to that operator and proposed operations into new areas of en route operation using previously approved aircraft and navigational systems.

(1) Due to the complex nature of air navigation, navigational requirements of domestic and international operations, and the wide variation in Air Traffic Control (ATC) separation standards used in these operations, inspectors must evaluate each proposed operation while considering the following factors and assessing the underlying infrastructure to ensure that it is compatible with the aircraft navigation equipment:

- The aircraft
- The navigational system(s)
- The communication system(s)
- The method or means of ATC surveillance used
- The flightcrew's training, skills, and recency of experience
- The area of proposed operation, including:
 - terrain
 - drift down
 - additional passenger oxygen requirements
 - suitable diversion/emergency airports
 - special airports
 - appropriate Traffic Alert and Collision Avoidance System (TCAS) requirements, if applicable

-any other unique performance requirements

- The operator's experience with different aircraft and navigation, communication, and surveillance systems in the area of proposed operations
- The operator's experience with the same aircraft and navigation, communication, and surveillance systems in different areas of operations
- Separation standards in the area of proposed operations
- The availability of alternate navigation capabilities
- Special areas of operation, (e.g., Reduced Vertical Separation Minima (RVSM), Areas of Magnetic Unreliability (AMU), Required Navigation Performance (RNP), Minimum Navigation Performance Specification (MNPS), etc.)

(2) This chapter provides standards for evaluating operations using navigational systems which have established operational characteristics and limitations within particular areas of en route operations. When an operator requests approval to use a means of navigation not addressed by these standards, the request must be forwarded through Regional Flight Standards Division to AFS-200. AFS-200, in coordination with AFS-400, will develop the necessary navigational concepts and provide national policies and guidance for evaluating such proposals.

B. The Objective of Air Navigation. In aviation, the following objectives of air navigation and navigational systems are necessary:

(1) The first objective is to avoid all obstacles while en route and to arrive safely and efficiently at the intended destination.

(2) The second objective is to efficiently fly an intended route with enough precision to permit ATC to safely separate aircraft.

C. General Concepts. Early in aviation, only a few aircraft operated within any given area at the same time. The most demanding navigational requirements were to avoid obstacles and arrive at the intended destination with enough fuel remaining to safely complete a landing. As aviation evolved, the volume of air traffic grew and a corresponding need to prevent collisions increased. Today, the most significant and demanding en route navigational requirement in aviation is the need to safely separate aircraft. There are several factors that must be understood concerning the separation of aircraft by ATC.

(1) When ATC does not have a means of surveillance, such as radar or Automatic Dependent Surveillance (ADS) to verify air traffic positions, ATC must rely entirely on pilot position reports relayed from an aircraft to determine its actual geographic position and altitude. In this situation, a flightcrew's precision in navigating the aircraft and their providing accurate position reports are critical to ATC's ability to provide safe separation.

(2) When ATC does have a means of surveillance to verify the aircraft's position, precise navigation and position reports, when required, are a means of providing safe separation. Flight safety in Instrument Flight Rules (IFR) operations depends directly on the operator's ability to achieve and maintain certain levels of navigational performance. ATC radar or ADS is used to monitor navigational performance, detect navigational deviations, and expedite traffic flow.

(3) The control of air traffic requires that a certain level of navigational performance be achieved by aircraft operating under Visual Flight Rules (VFR) to ensure safe separation of aircraft and to expedite the flow of air traffic.

(a) During cruising flight, the VFR flight altitude appropriate to the direction of flight must be maintained to ensure the required vertical separation between VFR and IFR aircraft and to assist in the prevention of collision between VFR aircraft.

(b) Any aircraft operating in accordance with ATC instructions must navigate with the level of accuracy required to comply with ATC instructions.

(c) If a clearance to enter controlled airspace has not been received, the flightcrew must navigate the aircraft with sufficient precision to avoid that airspace.

(d) A pilot must navigate VFR aircraft with sufficient precision to:

- Avoid weather conditions that would prevent visual contact with terrain and other aircraft.
- Locate a suitable airport and land safely without requiring assistance from ATC

3. U.S. PUBLIC LAW, REGULATIONS, INTERNATIONAL AGREEMENTS, AND INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) STANDARDS (SEE ORDER 8400.10 VOLUME 1, CHAPTER 2, INTERNATIONAL AVIATION, FOR MORE INFORMATION ON ICAO).

A. General.

(1) *Protection of Persons and Property.* The need to ensure protection of persons and property both in flight and on the ground is fundamental to the Regulations. Many of the design and performance requirements in aircraft certification rules are established to provide this protection. This protection is also extensively addressed in the operating and equipment rules related to air navigation. It is important that the regulations provide this protection equally to persons and property in flight and on the ground. Approvals of route and areas of en route operation must take into account the need to protect persons and property in flight and on the ground.

(2) *Title 49 of the United States Code (49 U.S.C.) (formerly, the Federal Aviation Act of 1958 (FA Act)).* The authorities and responsibilities of the FAA related to air navigation and navigation systems, practices, and procedures originate in 49 U.S.C. Two important sections of the act are summarized as follows:

(a) Title 49 of the United States Code (49 U.S.C.), § 40103 (formerly, § 307 of the FA Act) states that "The Secretary of Transportation is authorized and directed to develop plans for and formulate policy with respect to the use of the navigable airspace; and assign by rule, regulation, or order the use of the navigable airspace under such terms, conditions, and limitations, (operational procedures and navigation performance requirements) as he may deem necessary in order to ensure the safety of aircraft and the efficient utilization of such airspace."

(b) 49 U.S.C., § 44701 (formerly, § 601(a) of the FA Act) empowers the Secretary to "promote safety of flight of civil aircraft in air commerce by prescribing and revising from time to time . . . minimum standards governing the . . . performance of aircraft . . . and appliances (navigation performance and navigation systems) as may be required in the interest of safety . . . reasonable rules and regulations, or minimum standards, governing other practices, methods, and procedure . . . necessary to provide adequately for national security and safety in air commerce."

(3) *Articles of the ICAO Convention.* The Articles of the Convention represent international law and are equiva-

lent to the FA Act. The foundation for ICAO was established on December 7, 1944, when the text of the convention was opened for signature in Chicago, Illinois. This document (DOC 7300) is referred to as the “ICAO Convention” or the “Chicago Convention.” This “Convention” contains 96 Articles known as the Articles of the Convention. By signing the Convention, a government (State) agreed to abide by “certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically.” The Articles of the Convention represent those certain principles and arrangements and serve as the foundation for international aviation laws, standards, recommended practices and guidance material. Articles 44 through 66 established ICAO as a body within the United Nations. Articles 1 through 43 established general principles concerning international air navigation. The following are some of the more significant articles that relate to air navigation:

- Article 1 recognizes that each State has complete and exclusive sovereignty over the airspace above its territory.
- Article 3 states that the convention applies only to civil aircraft and that each State will require their state aircraft to operate with due regard for the safety of navigation of civil aircraft.
- Article 11 requires that the international air navigation laws and regulations of a contracting State relating to “the operation and navigation of such aircraft while within its territory, shall be applied to the aircraft of all contracting States without distinction to nationality, and shall be complied with by such aircraft upon entering or departing from or while within the territory of that state.”
- Article 12 is the most significant requirement related to flight operations (Rules of the Air). This Article requires that “each contracting State undertakes to adopt measures to ensure that every aircraft over or maneuvering within its territory and that every aircraft carrying its nationality mark, wherever such aircraft may be, shall comply with the rules and regulations relating to the flight and maneuver of aircraft, there in force.” This Article also requires that “over the high seas, the rules in force shall be those established under this convention. Each contracting State undertakes to ensure the prosecution of all persons violating the regulations applicable.”
- Article 37 requires each contracting State to achieve the highest practicable degree of uniformity with ICAO standards and recom-

mended practices, in matters related to the safety, regularity, and efficiency of air navigation.

(4) *The ICAO Annexes.* The Articles of the ICAO convention contain basic principles that are the foundation for ICAO annexes. ICAO annexes contain the Standards and Recommended Practices (SARPs) that have been adopted through international agreement to ensure the safety, regularity, and efficiency of air navigation. An ICAO standard is worded in mandatory language (shall, must, will) and is directive in nature. A recommended practice is worded in permissive language (should, may, can) and is not directive. Recommended practices represent practices that, although internationally recognized as safe operating practices, are not sufficiently comprehensive or lack the mature development appropriate for an international standard. The following are the ICAO annexes that are most significant to FAA operations inspectors:

- Annex 1, Personnel Licensing; Paragraph 3.4, Flight Radiotelephone Operator
- Annex 2, Rules of the Air
- Annex 6, Operation of Aircraft
- Annex 11, Air Traffic Services.

(a) *ICAO Annex 1, Personnel Licensing; Paragraph 3.4, Flight Radiotelephone Operator.* This paragraph addresses international telecommunication conventions.

(b) *ICAO Annex 2, Rules of the Air.* Annex 2 specifies international rules of the air agreed upon by ICAO member States. These rules are equivalent to the U.S. rules for operating within the territory of the United States (part 91). However, for operations over the high seas, Annex 2 is unique since it relates to flight and maneuver of aircraft within the meaning of Article 12 of the convention. Over the high seas, Annex 2 applies without exception (compliance is mandatory for all civil aircraft). Annex 2 is incorporated by reference into part 91. Part 91, section 91.703(a) requires each person operating a civil aircraft of U.S. registry outside the United States to comply with Annex 2 when operating over the high seas. The sections of Annex 2 most relevant to the discussion of air navigation are Chapter 3, General Rules, and Chapter 5, Instrument Flight Rules.

i. Chapter 3, paragraph 3.3 specifies requirements for ATC flight plans and paragraph 3.6 specifies requirements for ATC services.

ii. Chapter 3, paragraph 3.6.2 requires an aircraft to adhere to its “current flight plan” (currently effective ATC clearance), to operate along the defined centerline of any air traffic service (ATS) route used, and on any other route to operate directly between the points defining that route.

iii. Chapter 3, paragraph 3.6.5 requires that the flightcrew of any aircraft operated as a controlled flight to maintain a continuous listening watch on and establish two-way communication as necessary with (as required for air traffic control) the appropriate radio frequency of the appropriate ATC unit.

iv. Chapter 5, paragraph 5.1.1 requires aircraft to be equipped with suitable instruments and navigational equipment appropriate to the route the pilot will fly.

v. Chapter 5, paragraph 5.2.1 requires all IFR flights to comply with the provisions of paragraph 3.6 when operating in controlled airspace (see previous discussion in subparagraphs (b) and (c)).

vi. These requirements, as specified in chapters 3 and 5 of Annex 2, mean that the aircraft must be navigated to the degree of accuracy required for ATC. Flightcrews must maintain a continuous listening watch and communicate with ATC as necessary for the purpose of ATC.

(c) ICAO Doc 7030, Regional Supplementary Procedures, forms the procedural part of the Air Navigation Plan developed by ICAO Regional Air Navigation (RAN) Meetings to meet those needs of specific areas that are not covered in the world-wide provisions. Flightcrews must be aware of the regional procedures and NOTAMs for the areas in which they plan on operating, which complement the statement of requirements for facilities and services contained in the Air Navigation Plan publications. Procedures of world-wide applicability are either included in Annexes to the Convention on International Civil Aviation as Standards and Recommended Practices (SARPs) or they form part of one of the documents entitled "Procedures for Air Navigation Services (PANS)."

(d) *ICAO Annex 6, Operation of Aircraft.* Annex 6 has two parts applicable to fixed-wing aircraft. Part I specifies requirements for airplanes engaged in scheduled international air services and nonscheduled international air transport operations for compensation or hire. Part I applies to airplanes operated under 14 CFR Parts 121 and 135. Part II specifies requirements for international general aviation operations. The purpose of Annex 6, Part I is to facilitate safety in international airspace by providing standards for safe navigational operating practices. Part I also contributes to the efficiency and regularity of international air navigation by encouraging States to facilitate passage of other States' airplanes over their territories by operating in conformity with such standards. The application of Annex 2 to international operations differs slightly from Annex 6. A state may take exception (have different criteria) to Annex 2 standards for operations conducted in its sovereign airspace. However, no state can take exception to Annex 2 standards for operations conducted over the high seas. Annex 2, which specifies the international rules of the air, applies to all operations over the high seas without exception. Under Annex 6

standards, a state may take exception for operations in its sovereign airspace and for operation of its aircraft over the high seas. For air navigation, the most relevant section of Annex 6 is Chapter 7, Aeroplane Communication and Navigation Equipment. This chapter contains ICAO SARPs related to navigation and communication. Pertinent elements of these SARPs are described as follows:

i. Communication. Each airplane must have radio communication equipment capable of receiving meteorological information during the flight and conducting two-way communication at any time during the flight with aeronautical stations on frequencies prescribed by the appropriate authority. This requirement cannot be routinely satisfied by relaying reports through other aircraft.

ii. Navigation Equipment. Each airplane must have navigational equipment that enables it to proceed in accordance with its operational flight plan and the requirements of ATC services. Operations in MNPS airspace or routes or airspaces with an RNP specification require navigational equipment that continuously provides information to the flightcrew of adherence to or departure from track with respect to the required degree of accuracy at any point along that track. Any operation in MNPS or RNP routes or airspace must be authorized by the State responsible for that operator.

iii. Equipment Redundancy. Each airplane must have enough navigation equipment installed and operational to ensure that, if one item of equipment fails at any time during the flight, the remaining equipment will be sufficient to enable navigation to the degree of accuracy required for ATC. Additionally, failure of any single unit required for communication or navigation purposes, or both, must not result in the loss of another required unit.

(e) *ICAO Annex 11.* Annex 11 pertains to the establishment of airspace, units, and services necessary to promote a safe, orderly, and expeditious flow of air traffic. A clear distinction is made between ATC service, flight information service, and alerting service. Its purpose, together with Annex 2, is to ensure that flying on international air routes is carried out under uniform conditions designed to improve the safety and efficiency of air operation. The SARPs in Annex 11 apply in those parts of the airspace under the jurisdiction of a Contracting State where air traffic services are provided and a Contracting State accepts the responsibility of providing air traffic services over the high seas or in airspace of undetermined sovereignty. A Contracting State accepting such responsibility may apply the SARPs in a manner consistent with that adopted for airspace under its jurisdiction.

B. Relationship Between Title 14 of the Code of Federal Regulations (14 CFR), ICAO Annexes, and Foreign National Regulations. 49 U.S.C. is the authority for 14 CFR. 14 CFR represents the regulatory implementation of the responsibilities assigned by the U.S.C. and the imple-

mentation of the principles derived from the ICAO convention. The relationship between 14 CFR, ICAO Annexes, and foreign national regulations are discussed in the following subparagraphs.

(1) *Relationships of 14 CFR Part 91 to ICAO Annexes and Foreign National Regulations.* Part 91 regulates the operation of all civil and public aircraft within the United States and specifies minimum capabilities necessary to navigate to the degree of accuracy required for air traffic control. It also regulates the operation of civil aircraft of U.S. registry outside the United States. The following are examples of part 91 regulations applicable outside the U.S.:

(a) Section 91.703 requires each person operating a U.S. aircraft to comply with ICAO Annex 2 when over the high seas and to comply with the regulations of a foreign country when operating within that country's airspace.

(b) Section 91.703(a)(3) requires compliance with part 91 when not in conflict with the regulations of a foreign nation or Annex 2.

(2) *Relationships of 14 CFR Part 121 to ICAO Annexes and Foreign National Regulations.* These regulations are in addition to part 91 requirements in paragraph (1) above. For operators conducting operations under part 121, § 121.1 requires compliance with that part while operating within or outside the U.S. Part 121 § 121.11 specifies that these operators, when operating within a foreign country, must comply with the following:

(a) Rules of the country concerned and any local airport rules that may be in force.

(b) All rules of part 121 that are more restrictive than a foreign country's rules must be followed, if it can be done without violating the rules of that country.

(c) Annex 2 when over the high seas, in accordance with § 91.703.

(3) *Relationships of Title 14 CFR Part 125 to ICAO Annexes and Foreign National Regulations.* The regulations listed below are in addition to part 91 requirements. For operators conducting operations under part 125, § 125.23 requires compliance with that part while operating within and outside the U.S. and specifies that these operators, when operating within a foreign country, must comply with the following:

(a) Rules of the country concerned and any local airport rules that may be in force.

(b) All rules of parts 125, 61, and 91 that are more restrictive than a foreign country's rules must be followed, if it can be done without violating the rules of that country.

(c) Annex 2 when operating over the high seas, in accordance with § 91.703.

(4) *Relationships of 14 CFR Part 135 to ICAO Annexes and Foreign National Regulations.* The following regulations are in addition to part 91 requirements. For operators conducting operations under part 135, section 135.3 requires compliance with that part while operating within the U.S. It also specifies that while operating outside the U.S., these operators must comply with the following:

(a) Rules of the country concerned [and any local airport rules that may be in force], when operating within that country.

(b) All the regulations of 14 CFR parts 61, 91, and 135, which are more restrictive than Annex 2 or regulations of a foreign country when compliance with these U.S. regulations would not violate requirements of Annex 2 or the foreign country.

(c) Annex 2, when operating over the high seas, in accordance with section 91.703.

(5) *Relationship of 14 CFR Part 91, Subpart K, to ICAO Annexes and Foreign National Regulations.* Part 91 regulates the operation of all civil and public aircraft within the United States and specifies minimum capabilities necessary to navigate to the degree of accuracy required for air traffic control. For program managers conducting operations under part 91, subpart K, section 91.701 requires compliance with that part while operating within the U.S. In addition to the sections of part 91 that regulate civil aircraft of U.S. registry outside the United States, the program managers must comply with the following:

(a) Rules of the country concerned and any local airport rules that may be in force.

(b) All regulations of parts 61, 91, and part 91, subpart K that are more restrictive than a foreign country's rules must be followed, if it can be done without violating the rules of that country.

C. Relationship of U.S. 14 CFR To Air Navigation.

(1) 14 CFR related to air navigation have been promulgated and frequently changed to accommodate the need to efficiently handle a continuous growth in air traffic. Significant advances in air navigation technology, ATC techniques, and ATC equipment have permitted and required these regulations to evolve to their current status. Over the past years, numerous operational Regulations have been adopted to specifically satisfy the critical air navigation objective of safely separating aircraft. Certain Regulations, such as those requiring filing an ATC flight plan and complying with ATC clearances, are clearly related to this objective. Other 14 CFR provisions are not as clearly related, but have a direct bearing on the overall plan used to separate aircraft. The ATC system presumes compliance with all of the regulations related to air navigation. Any

noncompliance with these regulations can seriously degrade the ability to separate aircraft.

(2) *Title 14 CFR Part 91 Air Navigation Relationships.* Examples of operational 14 CFR related to air navigation and the objective of safely separating aircraft include the following:

(a) Part 91, § 91.123, Compliance with ATC clearances and instructions.

(b) Section 91.129, Operation in Class D airspace.

(c) Section 91.130, Operation in Class C Airspace.

(d) Section 91.131, Operation in Class B airspace.

(e) Section 91.137, Temporary flight restrictions.

(f) Section 91.135, Operations in Class A airspace.

(g) Section 91.143, Flight limitation in the proximity of space flight operations.

(h) Section 91.157, Special VFR weather minimums.

(i) Section 91.159, VFR cruising altitude or flight level.

(j) Section 91.169, IFR Flight plan; information required.

(k) Section 91.173, ATC clearance and flight plan required.

(l) Section 91.179, IFR cruising altitude or flight level.

(m) Section 91.181, Course to be flown.

(n) Section 91.511, Radio equipment for overwater operations

(o) Section 91.703, Operations of Civil Aircraft of U.S. Registry Outside of the U.S.

(p) Section 91.705, Operations within airspace designated as Minimum Navigation Performance Specifications airspace.

(q) Section 91.706, Operations within airspace designated as Reduced Vertical Separation Airspace.

D. Regulations Specifying Air Navigation Equipment Requirements. Many Regulations require specific aircraft equipment. These requirements relate directly to the air navigation objective of safely separating aircraft. Some of these equipment rules specifically relate to the operational requirement of navigating to the degree of accuracy required for ATC. The air navigation equipment rules of parts 121, 125, and 135 are often supplemented by Operations Specifications (OpSpecs) which contain specific authorizations,

limitations, and conditions that must be complied with by operators conducting flights under those 14 CFR parts. The following discussion references air navigation equipment requirements and provides direction, guidance, and clarification when appropriate.

(1) *Title 14 CFR Part 91 Air Navigation Equipment Requirements.* Certain subparts of part 91 specify navigation and communications equipment necessary for operations in the U.S. NAS. The following are examples of part 91 equipment requirements, with clarification when appropriate. Inspectors should read the appropriate 14 CFR in conjunction with this material.

(a) Section 91.171, VOR equipment check for IFR operations.

(b) Section 91.205, Powered civil aircraft with standard category U.S. airworthiness certificates, instrument, and equipment requirements.

- Section 91.205(d)(2) requires air navigation equipment to be appropriate to the ground facilities used. The current U.S. National Airspace System (NAS) is based on VHF Omnidirectional Range (VOR) and VOR/Distance Measuring Equipment (DME) ground facilities. Therefore, this regulation requires that VOR and/or VOR/DME equipment or an area navigation system that meets the en route criteria of the appropriate Advisory Circular (AC) or equivalent be installed in the aircraft and operable if it is to be used for IFR flight in U.S. national airspace. This navigational equipment is necessary to navigate to the degree of accuracy required for ATC. If the route to be flown is predicated on Nondirectional Beacon (NDB), then Automatic Direction Finder (ADF) airborne equipment is also required.
- Section 91.205(e) requires approved DME equipment when operating at or above 24,000 feet MSL if the route or route segment is predicated on VOR. DME is not required, for example, when navigation is based on the use of an Area Navigation (RNAV) system that meets the appropriate AC or equivalent en route performance and reliability criteria (or equivalent) without input from DME.

(c) Section 91.209, Aircraft lights.

(d) Part 91, § 91.215, ATC transponder and altitude reporting equipment and use.

(e) Section 91.217, Data correspondence between automatically reported pressure altitude data and the pilot's altitude reference.

(f) Section 91.219, Altitude alerting system or device (turbojet powered civil airplanes).

(g) Section 91.221, Traffic alert and collision avoidance system and use.

(2) *Title 14 CFR Part 121 Air Navigation Equipment Requirements.* Part 121 specifies the navigational equipment necessary for all operations conducted under that part, including operations outside the United States. These requirements are in addition to the navigational equipment requirements of part 91, but do not require duplication of any equipment specified in part 91. All of part 121 en route requirements reflect the concept of "demonstrated ability." The following are examples of part 121 navigation equipment requirements. Inspectors should read the appropriate 14 CFR in conjunction with this material.

(a) *Section 121.93 and 121.113, Area and route requirements: General.* The air carrier must show that it is able to conduct satisfactory operations over the routes and areas in which it operates. Approvals in areas and on specific routes are granted in OpSpecs and listed by "area of en route operation" and specific route, when appropriate. The general requirements specified in §§ 121.93 and 121.113 are not applicable to Class II navigation. Certain OpSpecs stipulate requirements for operations in Class G airspace (see Volume 3, Chapter 1 of 8400.10).

(b) *Sections 121.95 (domestic/flag) and 121.115 (supplemental), Route width.* These regulations specify the lateral navigation considerations necessary for the control of air traffic in Class I navigation. Certain Part B OpSpecs address these requirements (see Volume 3, Chapter 1, Section 4, of 8400.10).

(c) Sections 121.103 and 121.121, En route navigational facilities.

i. Sections 121.103(a) and 121.121(a) implement the concept of "navigation performance" when conducting IFR Class I navigation and certain types of Class II navigation that use nonvisual ground aids. Nonvisual ground aids are electronic Navigational Aids (NAVAID), but not necessarily limited to VOR, DME, or NDB. Loran-C is an example of a navigation system considered to be a nonvisual ground aid. Each part 121 operator must show that nonvisual ground aids are available and located to allow navigation to the degree of accuracy required for ATC and the type of operation involved.

ii. Area navigational systems that are certified for IFR flight in areas where Domestic ATS procedures are applied meet the intent of §§ 121.103 and 121.121 when conducting Class I navigation (including space-based systems such as GPS).

iii. Certain long-range operations may be conducted under these regulations using the following navigational equipment:

- Automatic Loran C systems certificated under AC 20-121, Airworthiness Approval of Airborne Loran-C Navigation Systems for Use in the U.S. National Airspace System (NAS), as amended
- Operations using approved satellite-based systems such as GPS

iv. When operating in the U.S. Class A airspace, area navigation systems that have not been demonstrated to meet the criteria for IFR flight in areas where Domestic ATS procedures are applied also meet the intent of these rules, provided the ATC radar is serviceable and dual airborne VOR/DME equipment is installed and operable. OpSpecs provide authorization to conduct operations in the U.S. positive control area (PCA) using these area (or long-range) navigation systems (see Volume 3, Chapter 1 of 8400.10).

v. Sections 121.103 and 121.121 do not specifically state or imply a redundant navigation equipment capability. In addition, these regulations do not apply to VFR pilotage operations, operations with a flight navigator or long-range navigation operations using an Inertial Navigation System (INS).

(d) Section 121.305, Flight and navigational equipment.

(e) Section 121.323, Instrument and equipment for operations at night.

(f) Section 121.325, Instruments and equipment for operations under IFR or over the top.

(g) Section 121.345, Radio equipment.

(h) Section 121.347, Radio equipment for operations under VFR over routes navigated by pilotage.

i. If the route is navigated using an area navigational system, radio navigational signals compatible with the airborne area navigational system must be available if required for the system to perform its intended function. Unless the route is navigated using an area navigation system certified for IFR flight in accordance with criteria in the appropriate guidance, airborne VOR equipment is required when the route is predicated on VOR. Airborne ADF equipment is required when it is predicated on NDB.

ii. Although section 121.611 permits VFR en route operations, part 121 operators are generally prohibited from conducting VFR en route operations by part B of the operations specifications. Certain part 121 operators may be specifically authorized to conduct VFR en route operations in special situations (see volume 3, chapter 1.)

iii. This rule does not apply to Class II navigation.

NOTE: Section 121.347(b) specifies that for night VFR pilotage operations, the airplane must be equipped with the radio equipment necessary to receive radio navigational signals applicable to the route flown.

(i) Sections 121.349, Radio equipment for operations under VFR over routes not navigated by pilotage or for operations under IFR or over the top. The essential requirement of this regulation is that airplanes must be equipped to receive radio navigational signals from all primary en route and approach navigational facilities intended to be used.

i. The intent of this regulation is to require redundant airways navigation capability (VOR, VOR/DME, and NDB) to ensure the ability to navigate to the degree of accuracy required for ATC when conducting Class I navigation. Sections 121.103 and 121.121 clearly state that nonvisual ground aids are not required for operations over routes where celestial or other means of navigation are approved by the Administrator. Since all IFR primary en route and approach navigation facilities have historically been nonvisual ground aids (Standard ICAO ground-based NAVAIDs), § 121.349 is intended to apply only to operations over routes predicated on VOR, VOR/DME, or NDB.

ii. Section 121.349 applies to both Class I and Class II navigation operations. Sections 121.103, 121.121, and 121.389 apply to Class II navigation operations. The intent of section 121.349 is met when any Class I navigation operation is predicated on the following:

- VOR, provided dual independent VOR equipment is installed and operable in the airplane.
- NDB, provided dual independent ADF equipment is installed and operable in the airplane. However, if one ADF system and a dual independent VOR system are installed and operable, the intent of section 121.349 is met provided VOR NAVAIDs are located at ground positions that would permit the flight to safely proceed (from any point along the route) to a suitable airport and complete an instrument approach without using ADF equipment.
- Area navigational systems, provided either dual independent area navigation systems certified under the appropriate guidance are installed and operable or if the capability exists to revert to VOR or NDB, a single RNAV system is installed and operable.

- Part B of the OpSpecs permits (under specified conditions) an area navigational system fix to be substituted for an ICAO ground-based NAVAID when that facility is temporarily out of service.

(j) *Section 121.351, Radio equipment for extended overwater operations and for certain other operations.* This regulation applies to both Class I and Class II navigation operations. Sections 121.103, 121.121, and 121.389 apply to all other Class II navigation operations.

(k) *Section 121.357, Airborne weather radar equipment requirements.* Airborne weather radar is normally used for thunderstorm detection and avoidance.

(l) *Section 121.355, Equipment for operations on which specialized means of navigation are used.* This regulation limits the definition of “specialized means of navigation,” such as INS operations, when operating outside the United States. Section 121.355 is referenced in § 121.389 which requires “specialized means of navigation” (INS or IRS) to be approved in accordance with § 121.355. GPS, INS, and IRS are long-range navigation systems that can be used to satisfy the requirements of Class II navigation.

(m) *Section 121.389, Flight navigator and specialized navigation equipment.* The conceptual basis of this regulation is the phrase “when its position cannot be reliably fixed for a period of more than 1 hour.”

i. “Reliably fixed,” as defined in the OpSpecs, is a station passage of a VOR, VORTAC, or NDB waypoint. A “reliable fix” also includes a VOR/DME fix, an NDB/DME fix, a VOR intersection, an NDB intersection, and a VOR/NDB intersection, provided course guidance is available from one of the facilities and the fix lies within the operational service volume of both facilities that define the fix. A “reliable fix” also includes positioning information obtained from an IFR certified area navigation system, such as GPS, LORAN C, or DME/DME updated Flight Management System (FMS).

ii. Section 121.389 does not apply to those situations where the airplane's position can be reliably fixed, at least once each hour to the degree of accuracy required for the control of air traffic. If the operator can show compliance with §§ 121.103/121.121, the requirements of 14 CFR § 121.389 are automatically met by providing fixes more frequently than once an hour. Therefore, Class II navigation operations using a GPS system meets the requirements of §§ 121.103 or 121.121 and are approved under these regulations.

iii. Class II operations with an INS system are approved under part 121, § 121.355 and Appendix G.

iv. Class II navigation systems are divided into two categories.

- INS, IRU, and IRS (inertial systems) are defined as “specialized means of navigation,” as addressed in §§ 121.389 and 121.355. They are self-contained, electronic dead reckoning systems that have no “position fixing” capabilities.
- Loran C and GPS are “position fixing” or “position keeping” devices that receive their signals from an external source. Loran C and GPS are nonvisual ground and space-based aids, respectively, and are addressed in §§ 121.103 and 121.121, en route navigational facilities.

(3) *Title 14 CFR Part 125 Air Navigation Equipment Requirements.* Part 125 specifies the navigation and communications equipment necessary for all operations under part 125, including part 125 operations outside the United States. These requirements are in addition to the navigation and communications equipment requirements of part 91, but do not require duplication of any equipment specified in part 91. The following are examples of part 125 navigation and communications equipment requirements, with clarification, when appropriate. Inspectors should read the appropriate 14 CFR in conjunction with this material.

(a) Section 125.203, Radio and Navigation Equipment.

(b) Section 125.244, Traffic Alert and Collision Avoidance System.

(c) Section 125.225, Flight Recorders.

(d) Section 125.266, Digital Flight Data Recorders.

(e) Section 125.277, Cockpit Voice Recorders.

(f) Section 125.267, Flight Navigator and Long-Range Navigation Equipment.

(4) *Title 14 CFR Part 135 Air Navigation Equipment Requirements.* Part 135 specifies the navigation and communications equipment necessary for all operations under part 135, including part 135 operations outside the United States. These requirements are in addition to the navigation and communications equipment requirements of part 91, but do not require duplication of any equipment specified in part 91. The following are examples of part 135 navigation and communications equipment requirements, with clarification, when appropriate. Inspectors should read the appropriate 14 CFR in conjunction with this material.

(a) Section 135.143, General requirements.

(b) Section 135.149, Equipment requirements: General.

(c) Section 135.159, Equipment requirements: Carrying passengers under VFR at night or under VFR over the top conditions.

(d) Section 135.161, Radio and navigation equipment: Carrying passengers under VFR at night or VFR over the top. Section 135.161 requires radio navigational equipment able to receive radio signals from the ground facilities to be used. The ground facilities and airborne equipment used must enable navigation to the degree of accuracy required for ATC. Airborne equipment requirements must also comply with part B of the OpSpecs.

- If the route is navigated using an area navigation system installed in accordance with the appropriate guidance the installed area navigation equipment must be operable. VOR and/or ADF equipment are not required for en route operation dispatch where an area navigation system certified for IFR flight is installed, in accordance with the applicable guidance, and operable. Additionally, all ground-based or space-based elements of the support system must be operational at dispatch.
- Unless the route is navigated using an area navigation system certified for IFR flight in accordance with appropriate ACs, VOR equipment must be installed and operable if the route is predicated on VOR. ADF equipment must be installed and operable if the route is predicated on NDB.

(e) Section 135.163, Equipment requirement: Aircraft carrying passengers under IFR.

(f) Section 135.165, Radio and navigation equipment: Extended overwater or IFR operation.

- The requirements of § 135.165 apply to both Class I and Class II navigation equipment requirements. Part 135 Class II navigation requirements are specified in part B of the OpSpecs.
- This regulation requires two independent systems for navigation compatible with the facilities to be used. For en route navigation (excluding terminal operations), the facilities that must be used, whether self-contained, ground-based, or space-based, must enable navigation to the degree of accuracy required for ATC. Airborne equipment requirements must also comply with part B of the OpSpecs.
- If the route is navigated using an area navigation system installed and approved in

accordance with the en route criteria of the applicable ACs, two independent area navigation systems must be installed and operable. Dual VOR and/or dual ADF equipment is not required for en route operations when two independent area navigation systems, certified for IFR flight in accordance with the applicable ACs, are installed and operable and all elements of the support facilities are serviceable. For example, two independent GPS systems or one independent GPS system and some other approved independent area navigation system would be acceptable configurations.

- Part B of the OpSpecs permits (under specified conditions) an approved area navigation system fix to be substituted for an ICAO ground-based NAVAID when that facility is temporarily out of service.
- Unless routes are navigated using an area navigation system certified for IFR flight in accordance with the appropriate ACs, two independent VOR systems must be installed and operable if the route is predicated on VOR and two independent ADF systems must be installed and operable if the route is predicated on NDB. Section 135.165 (d) allows for the installation and use of a single long-range navigation system in specific geographic areas. This may be authorized by the issuance of OpSpec B054, Class II Navigation Using Single Long-Range navigation System (S-LRN).

(g) Section 135.175, Airborne weather radar equipment requirements.

(h) *Section 135.215, IFR: Operating limitations.* This regulation specifies the degree of accuracy required when operating IFR outside of controlled airspace, e.g., Class G airspace and/or at an airport without an operating control tower. It also reflects the concept of “demonstrated ability” to safely conduct operations. See OpSpecs A014, C064, and C080 in Order 8400.10, volume 3, chapter 1, section 3.

5. NAVIGATION CONCEPTS.

A. Concept of Navigation Performance. The concept of navigation performance involves the precision that must be maintained for both the assigned route and altitude by an aircraft operating within a particular area. Navigation performance is affected by the deviation (for any cause)

from the route of flight specified in the ATC clearance. This includes errors due to degraded accuracy and reliability caused by the design and maintenance of airborne and ground-based navigational equipment and the flightcrew's competency.

(1) The concept of navigational performance is fundamental to the Regulations and is best defined in 14 CFR part 121, sections 121.103 and 121.121, which state that each aircraft must be “navigated to the degree of accuracy required for air traffic control.” 14 CFR part 91, section 91.123 requirements related to compliance with ATC clearances and instructions also reflect this fundamental concept. The concept of navigational performance is also inherent in ICAO Standards and Recommended Practices (SARPs). For example, Annex 2 states that the aircraft “shall adhere to its current flight plan” (comply with the currently effective ATC clearance) and “when on an established air traffic service (ATS) route, operate along the defined centerline of that route.”

NOTE: Various ICAO Planning and Implementation Regional Groups (PIRG) are considering the implementation of strategic lateral offset procedures, to be used at the pilot's option, whereby properly equipped aircraft can be flown offset 1 or 2 nm to the right of centerline based on direction of flight. This procedure is designed to decrease the technical collision risk in the applicable airspace. An operational trial of this procedure is ongoing in the West Atlantic Rought System (WATRS).

(2) *RNAV (Area Navigation).* RNAV operations permit flight in any airspace with prescribed accuracy tolerances without the need to fly directly over ground-based navigation facilities. The application of RNAV techniques in various parts of the world has already been shown to provide a number of advantages over more conventional forms of navigation.

(3) *Required Navigation Performance (RNP).* Required Navigation Performance (RNP) is intended to provide RNAV performance standards that can be used and applied by aircraft and aircraft equipment manufacturers, airspace planners, aircraft certification and operations, pilots and controllers, and international aviation authorities. RNP, along with other aspects of communications, navigation, and surveillance, can be applied to obstacle clearance or aircraft separation requirements to ensure a consistent application level. RNP is a concept that applies to navigation performance within an airspace, and therefore affects both the airspace and the aircraft. RNP is intended to characterize an airspace through a statement of the navigation performance accuracy (RNP type) to be achieved within the airspace. The RNP type is based on a navigation performance accuracy value, which is expected to be achieved by the population of aircraft operating within the airspace 95% of the time. Required levels of navigation performance (standards) vary

from area to area, depending on traffic density and complexity of the routes flown. The implementation of RNP is part of ICAO's Global Air Navigation Plan for communication, navigation, and surveillance (CNS) and supports ICAO's air traffic management (ATM) concepts. The end state of the transition is the implementation of Free Flight, which allows user-defined trajectory. The development of the RNP concept recognizes that current aircraft navigation systems are capable of achieving a predictable level of navigation performance accuracy and that a more efficient use of available airspace can be realized on the basis of this navigation capability. The carriage of specialized navigation equipment is a requirement in some regions and may become a requirement in others.

B. Concept of Operational Service Volume. Operational service volume is that volume of airspace surrounding an ICAO standard airways navigation facility that is available for operational use. Within that volume of airspace, a signal of usable strength exists that is not operationally limited by co-channel interference. Within this volume of airspace (the operational service volume), an ICAO standard ground-based navigational aid (NAVAID) signal in space conforms to flight inspection signal strength and course quality standards including frequency protection. ICAO standard ground-based NAVAIDs are VOR, VOR/DME, and a Nondirectional Beacon (NDB). The Global Positioning Service (GPS) has been accepted by ICAO as a standard NAVAID. However, a distinction is made between "standard ground-based NAVAIDs" and "standard NAVAIDs." "Standard ground-based NAVAIDs" have an operational service volume and "standard NAVAIDs" do not. The NAS of ICAO contracting member States are based on the operational service volume of these ground-based facilities, but GPS, by virtue of its universal signal coverage, is not restricted to an operational service volume. Navigational performance within the operational service volume and ATC separation minimums can be predicated by the use of both standard ground-based NAVAIDs and standard NAVAIDs. The concept of operational service volume is critical for understanding and applying the principles of air navigation, as discussed in this handbook. Refer also to the Aeronautical Information Manual (AIM) for further discussion on operational service volume.

C. Categories of Navigational Operations. A thorough comprehension of the categories of navigational operations is essential to understand air navigation concepts and requirements discussed in this handbook and other documents. Understanding the categories of navigational operations is also essential for evaluating an operator's ability to navigate to the degree of accuracy required for the control of air traffic. In the broad concept of air navigation, two major categories of navigational operations are identified:

- Class I navigation
- Class II navigation

(1) *Class I navigation.* Class I navigation is defined as any en route flight operation conducted in controlled or Class G airspace that is entirely within operational service volumes of ICAO standard ground-based NAVAIDs (VOR, VOR/DME, NDB).

(a) The operational service volume describes a three-dimensional volume of airspace within which any type of en route navigation is categorized as Class I navigation. For any type of navigation within this volume of airspace, IFR navigational performance must be at least as precise as IFR navigation is required to be using VOR or VOR/DME. It is important to understand that the definition of Class I navigation is not dependent upon the equipment installed in the aircraft. For example, an aircraft equipped and approved to use Loran-C or GPS in the U.S. as the sole means of en route navigation is conducting Class I navigation when the flight is operating entirely within the operational service volume of federal VORs and VOR/DMEs. In this example, if IFR operations are to be conducted, the IFR navigational performance of the Loran-C or GPS must be as precise as IFR navigation is required to be using the ICAO standard ground-based NAVAIDs. In another example, a VFR flight navigated by pilotage is conducting Class I navigation when operating entirely within the operational service volume.

(b) A determination of the lateral and vertical extent of the airspace where Class I navigation is conducted is determined solely by the operational service volumes of ICAO standard ground-based NAVAIDs (see section 3 of this chapter.) Class I navigation cannot be conducted outside of this airspace. Class I navigation also includes VFR or IFR navigation operations on the following:

- Federal airways
- Published IFR direct routes in the U.S.
- Published IFR off airway routes in the U.S.
- Airways, advisory routes (ADRs), direct routes, and off airway routes published or approved by a foreign government, provided that these routings are continuously within the operational service volume (or foreign equivalent) of ICAO standard ground-based NAVAIDs

(c) Class I navigation requirements are directly related to separation minimums used by ATC. IFR separation minimums applied in the U.S. NAS and most other countries are based on the use of ICAO standard ground-based NAVAIDs. However, these separation minimums can only be applied by ATC within areas where the ground-based NAVAID signal in space meets flight inspection signal strength and course quality standards. An ICAO standard ground-based NAVAID signal in space conforms to flight inspection signal strength and course quality standards, including frequency protection, within its designated operational service volume. Therefore, air

navigation and the safe separation of aircraft within that service volume can be predicated on the use of these facilities.

(d) Within areas where the safe separation of aircraft is based on the use of ICAO standard ground-based NAVAIDs, any IFR operation must be navigated with at least the same accuracy as the accuracy specified by the appropriate national separation minimums. The illustration following this paragraph provides several examples of Class I navigation. A more detailed discussion of Class I navigation is in section 3 of this chapter.

(2) *Class II navigation.* Class II navigation is any en route operation that is not categorized as Class I navigation and includes any operation or portion of an operation that takes place outside the operational service volumes of ICAO standard ground-based NAVAIDs. For example, an aircraft equipped with only VOR conducts Class II navigation when the flight operates in an area outside the operational service volume of a VOR.

(a) Class II navigation involves operations conducted in areas where the signals from ICAO standard ground-based NAVAIDs have not been shown to meet flight inspection signal strength, course quality, and frequency protection standards. Therefore, ATC cannot predicate aircraft separation on the use of these facilities alone and must apply larger separation criteria.

(b) When operating outside the operational service volume of ICAO standard ground-based NAVAIDs, signals from these stations cannot be relied upon as the sole means of conducting long-range operations to the degree of accuracy required for the control of air traffic or as the sole means of obstacle avoidance. Therefore, when operating outside the designated operational service volumes of ICAO standard ground-based NAVAIDs, operators must use long-range navigation systems (LRNS) approved to navigate to the degree of accuracy required for the control of air traffic and to avoid obstacles. For information on LRNS, see Order 8400.10, volume 4, chapter 1, section 4, paragraph 117.

(c) It is important to understand that the definition of Class II navigation does not address the equipment installed in the aircraft. For any type of navigation within this volume of airspace, the IFR navigational performance must be at least as accurate as the navigational performance assumed during establishment of the ATC separation minimums for that volume of airspace.

(d) In the domestic U.S., it is not uncommon for VFR flights at low altitude to conduct Class II navigation while outside the operational service volumes of ICAO standard ground-based NAVAIDs. Class II navigation includes transoceanic operations and operations in remote land areas. A more detailed discussion of Class II navigation is provided in section 4 of this chapter.

D. Global Positioning System (GPS) and Wide Area

Augmentation System (WAAS) Navigation. GPS is a satellite-based radio navigation system that uses precise range measurements from GPS satellites to determine a precise position anywhere in the world. The GPS constellation consists of a minimum of 24 satellites in various orbital planes approximately 11,000 nautical miles (NM) above the earth. The satellites broadcast a timing signal and data message that the airborne equipment processes to obtain satellite position and status data and to measure how long each satellite's radio signal takes to reach the receiver. By knowing the precise location of each satellite and precisely matching timing with the atomic clocks on the satellites, the receiver can accurately measure the time the signal takes to arrive at the receiver. Thus, the receiver can determine the satellite's precise position. A minimum of three satellites must be in view to determine a two-dimensional position. Four satellites are required to establish an accurate three-dimensional position. GPS equipment determines its position by precise measurement of the distance from selected satellites in the system and the satellite's known location. The accuracy of GPS position data can be affected by various factors. Many of these accuracy errors can be reduced or eliminated with mathematics and sophisticated modeling, while other sources of errors cannot be corrected. The following are examples of those errors that cannot be corrected:

- Atmospheric propagation delays can cause relatively small measurement errors, typically less than 100 feet. Ionospheric propagation delays can be partially corrected by sophisticated error-correction capabilities
- Slight inaccuracies in the atomic clocks on the satellites can cause a small position error of approximately 2 feet
- Receiver processing (such as mathematical rounding and electrical interference) may cause errors that are usually either very small, which may add a few feet of uncertainty into each measurement, or very large, which are easy to detect. Receiver errors are typically on the order of 4 feet.
- Conditions that cause signal reflections before the satellite's transmitted signal gets to the receiver can cause small errors in position determination or momentary loss of the GPS signal. While advanced signal processing techniques and sophisticated antenna design are used to minimize this problem, some uncertainty can still be added to a GPS measurement
- A satellite's exact measured orbital parameters (ephemeris data) can contain a small error of approximately 4 feet

(1) System Operation.

(a) The Department of Defense (DOD) is responsible for operating the GPS satellite constellation and constantly monitors the GPS satellites to ensure proper operation. Every satellite's ephemeris data are sent to each satellite for broadcast as part of the data message sent in the GPS signal. The GPS is a system of cartesian earth-centered, earth-fixed coordinates, as specified in the DOD World Geodetic System 1984 (WGS-84). Navigation values, such as groundspeed and distance and bearing to a way point, are computed from the aircraft's latitude/longitude and the location of the waypoint. Course guidance is usually provided as a linear deviation from the desired track of a great circle course between defined way points.

(b) GPS navigation capability from the 24-satellite constellation is available 24 hours a day anywhere in the world. GPS status is broadcast as part of the data message transmitted by the satellites. Additionally, system status is available through Notices to Airmen (NOTAM) and from the U.S. Coast Guard.

(c) GPS signal integrity monitoring will be provided by the GPS navigation receiver, using receiver autonomous integrity monitoring (RAIM). For GPS sensors that provide position data only to an integrated navigation system (e.g., FMS, multi-sensor navigation system), a level of GPS integrity equivalent to that of RAIM may be provided by the integrated navigation system. Availability of RAIM capability to meet non-precision approach requirements in the United States with the 24-satellite constellation is expected to exceed 99 percent.

(2) *Selective Availability (SA)*. Essentially, SA is a method by which DOD can artificially create a significant clock and ephemeris error in the satellites. This feature is designed to deny an enemy nation or terrorist organization the use of precise GPS positioning data. SA is the largest source of error in the GPS system. When SA is active, the DOD guarantees horizontal position accuracy will not be degraded beyond 100 meters, 95 percent of the time, and beyond 300 meters, 99.99 percent of the time. The U.S. began discontinuing the use of intentional degradation, SA, May 1, 2000 until 2006 with an annual assessment of its continued use. Civilian users will realize a dramatic improvement in GPS accuracy with the discontinuation of SA. It is envisioned that SA will not be turned on unless a national emergency exists or is imminent.

(3) TSO-C145a /C146a Avionics Equipment for Wide Area Augmentation Systems (WAAS).

(a) Wide Area Augmentation System (WAAS) has been developed to improve the accuracy, integrity, availability, and reliability of GPS signals. It is a safety critical system consisting of a ground network of reference and integrity monitor data processing sites which assess current GPS performance, as well as a space segment that broadcasts that assessment to GNSS users to support IFR

navigation. WAAS equipment has been designed to automatically use the WAAS data and ranging signal. The operational availability of navigation for WAAS-equipped operators in any given area may be ascertained by accessing the FAA NOTAM system. (See TSO-C145a/C146a and RTCA DO229B, Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment.)

(b) Recent developments in navigation technology include the availability of WAAS capable navigation systems approved under TSO-C145a/C146a. This equipment constitutes a significant improvement over the older GPS standards (TSO-C129) by the incorporation of new technology to provide enhanced signal integrity using WAAS, Fault Detection and Exclusion (FDE), and Receiver Autonomous Integrity Monitoring (RAIM). The improved navigation accuracy and flexibility of WAAS equipment will ultimately produce an increase in both system capacity and overall flight safety.

(c) TSO-C145a provides the certification standards for airborne navigation WAAS sensors, while TSO-C146a refers to a WAAS stand-alone airborne navigation system. TSO-C145a/C146a equipment must be installed in accordance with Advisory Circular (AC) 20-138A, Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment. For TSO-C145a equipment, the flight management system must comply with TSO-C115b and be installed in accordance with AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors. When all provisions are met, including the installation of dual independent systems, these systems may be authorized for use as the only means of conducting Instrument Flight Rules (IFR) Area Navigation (RNAV) in the U.S. National Airspace System (NAS).

(d) FDE technology allows WAAS equipment to automatically detect a satellite failure that effects navigation and to exclude that satellite from the navigation solution.

(e) Receiver Autonomous Integrity Monitoring (RAIM) is a function that considers the availability of satisfactory signal integrity broadcasted from the particular GPS satellites used during a given flight. Onboard GPS/WAAS navigators accomplish this automatically as the aircraft proceeds along its route. When insufficient signal integrity is detected a 'loss of integrity' or RAIM alert is provided to the flight crew. To support pre-flight planning, operators can identify outages that impact WAAS equipment through NOTAMs or by accessing an FAA-approved prediction program.

(f) Under present regulations, operators certificated in accordance with 14 CFR part 119 proposing to use WAAS equipment as the only means of IFR navigation must have a TSO-C145a/C146a approach capable navigation system installed and operating in their aircraft. In the event of a complete failure of WAAS and GPS navigation

capability operators must provide for reversion to another form of radio navigation or the navigation system must provide for an automatic positioning capability to ensure the flight can be safely continued to its destination or a suitable alternate.

(4) Use of WAAS in Alaska Operations.

(a) Principal Operations Inspectors should refer to volume 3, chapter 1, section 4, paragraph 71, part B OpSpecs, B030-IFR Navigation Using GPS/WAAS RNAV Systems, for issuance of OpSpecs that authorize WAAS RNAV operations in Alaska. OpSpec paragraph B030 is issued to those certificate holders identified in Section 1 of SFAR 97 for IFR en route RNAV operations in Alaska and its airspace on published air traffic routes using TSO-C145a/C146a navigation systems as the only means of IFR navigation. The OpSpec also authorizes TSO-C145a/C146a navigational systems to be used for IFR en route operations at Special Minimum En Route Altitudes (MEA) that are outside the operational service volume of ground-based navigation aids, if the aircraft operation meets the requirements of sections 3 and 4 of SFAR 97.

(b) SFAR 97 is applicable to U.S. and foreign operations conducted in Alaska under 14 CFR parts 91, 121, 125, 129, and 135. The SFAR allows IFR operations using dual TSO-C145a/C146a GPS/WAAS systems as the only means of navigation on federal airways and other published Air Traffic Service (ATS) routes in domestic airspace, both within and outside the operational service volume of ground based navigation aids. The rule also authorizes the use of GPS designated minimum en route altitudes (MEA) for aircraft using TSO-C145a/C146a systems. These GPS MEAs along applicable routes are indicated on IFR charts in blue followed by the letter "G." The SFAR also establishes training requirements for operators of TSO-C145a/C146a equipped aircraft including training in service degradation and equipment failure modes.

E. Concept of the Degree of Accuracy Required for Control of Air Traffic. The fundamental concept for all IFR navigation standards, practices, and procedures is that all IFR aircraft must be navigated to the degree of accuracy required for control of air traffic.

(1) When a flight adheres to the clearance assigned by ATC at all times, that aircraft is considered to be navigated to the degree of accuracy required for the control of air traffic. If an aircraft makes an unauthorized deviation from its assigned clearance, that aircraft has not been navigated to the degree of accuracy required for control of air traffic.

(2) ATC separation minimums establish the minimum lateral, vertical, and longitudinal distances that are used to safely separate aircraft operating within a specified area. Separation minimums also represent the minimum level of overall navigation performance and a buffer that can be accommodated at any time without jeopardizing safety of

flight. These separation minimums have been established for IFR operations in controlled airspace. These standards are usually established through international agreement and implemented through national regulations. These minimums are established for particular categories of navigational operation and specified areas. Examples of particular categories of navigational operations and specified areas include navigation on airways in the national airspace of ICAO member states and long-range navigation in oceanic or remote land areas.

(3) For operations where ATC services are provided by the United States, separation minimums are established by 14 CFR and ATC directives. For operations where air traffic services are provided by contracting ICAO member States, separation minimums are established by the national regulations of the member states (if established) and in ICAO documents. Operations in Class G airspace are not provided ATC services (aircraft are not separated by ATC). Separation minimums are not normally established for Class G airspace. The prevention of collision is dependent upon the "see and avoid" concept and other practices discussed in paragraph 73.

(4) Separation minimums applied for operations in the U.S. NAS can be found in FAA Order 7110.65, Air Traffic Control. FAA Order 7110.83, Oceanic Air Traffic Control, prescribes separation minimums in international oceanic airspace delegated to the U.S. by ICAO. ICAO Document 7030/4, Regional Supplementary Procedures, also prescribes separation minimums in international airspace.

7. THE CONCEPT OF AN ATC CLEARANCE. Issuance of an ATC clearance by a controller and the acceptance of this clearance by a pilot is a negotiation process that establishes conditions for the prevention of collision hazards (in flight and terrain).

A. When a controller issues an IFR clearance, the controller agrees to reserve a three-dimensional block of airspace for that aircraft along the route defined in that clearance. The controller also agrees to issue clearances to all other controlled air traffic, ensuring safe separation.

B. When a pilot accepts an ATC IFR clearance, the pilot agrees to continuously remain within that three-dimensional block of airspace assigned by ATC, and adhere to the rules of flight for that operation. The pilot is obligated to comply with the clearance unless amended or an emergency is declared.

C. The pilot is expected to navigate to the degree of accuracy required for air traffic control. A failure to navigate to the degree of accuracy required may create a flight safety hazard.

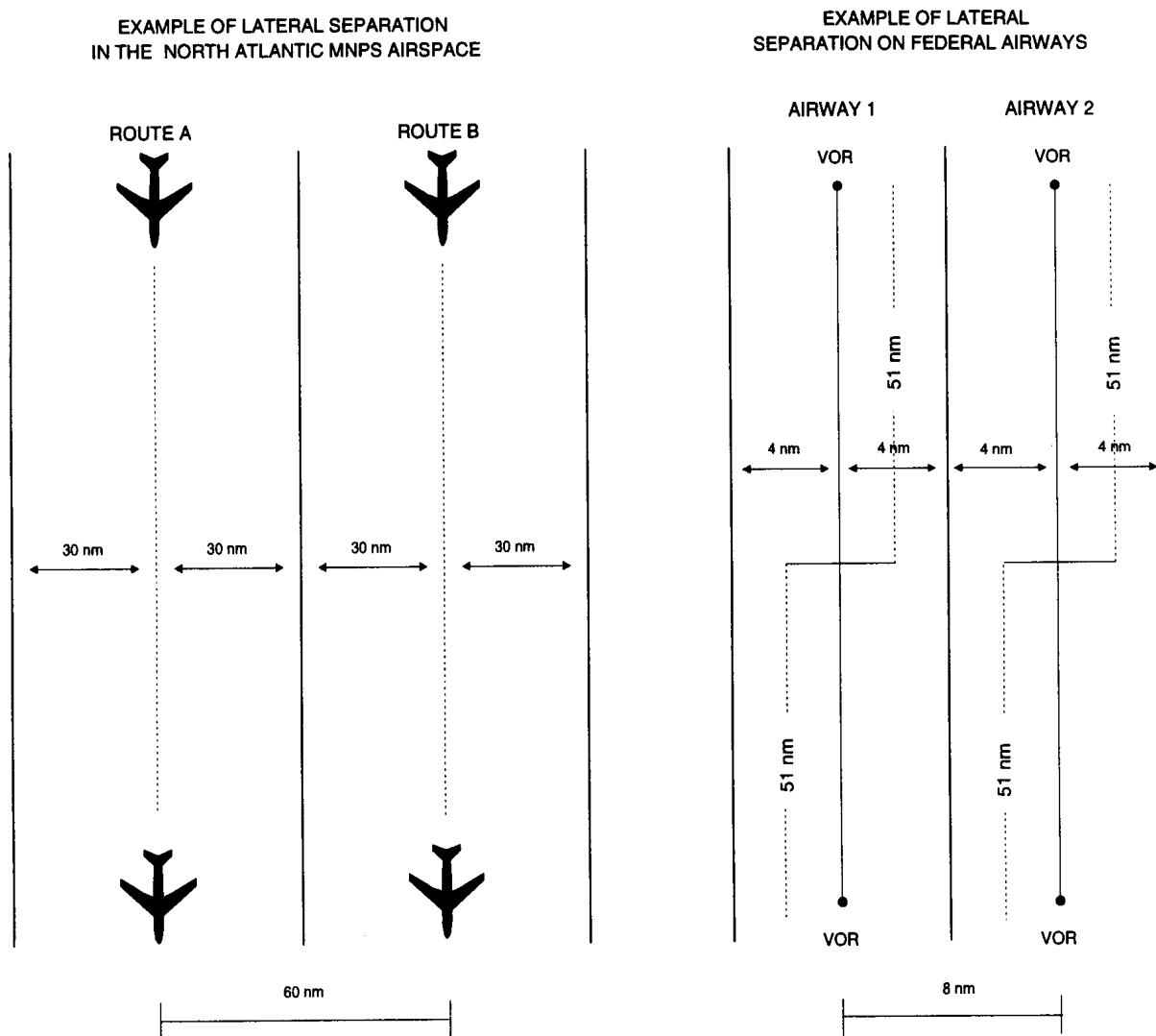
D. In a non-radar or non-ADS environment, ATC has no direct knowledge of the actual position of an aircraft or its

relationship to other aircraft in adjacent airspace. Therefore, ATC's ability to detect a navigational deviation and resolve collision hazards is seriously degraded when a deviation

from an agreed-to clearance occurs.

8 - 30 RESERVED.

FIGURE 4.1.1.1.
EXAMPLES OF LATERAL SEPARATION IN THE NORTH ATLANTIC MNPS AIRSPACE AND LATERAL SEP-
ARATION ON FEDERAL AIRWAYS



[PAGES 4-17 THROUGH 4-22 RESERVED]